Pozitron Emissziós Tomográfia

PET minőség-ellenőrzés

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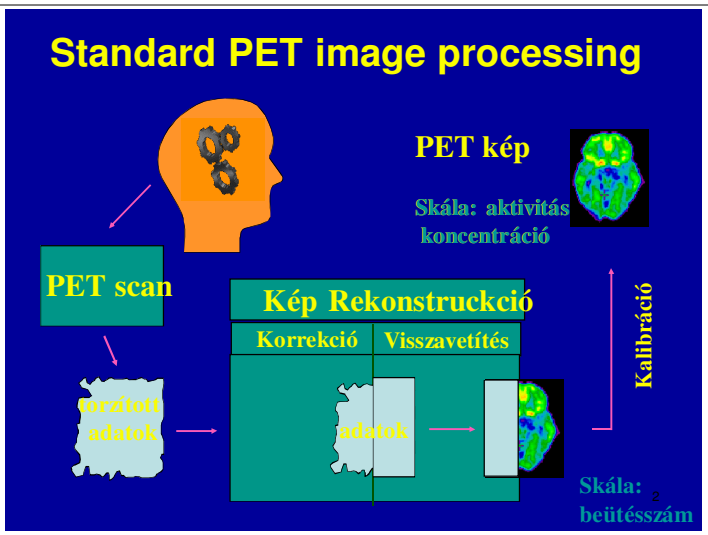
Nukleáris Medicina intézet

Standard PET image processing



Standard uptake value (SUV)

Az aktivitás koncentrációban kifejezett PET kép praktikus „tovább skálázása"

$$SUV\,(t_1,t_2) = \frac{ROI\ \ aktivitás\ \ koncentrác\ ió(t_1,t_2)}{beadott\ \ aktivitás\ /\ testsúly\ \ kg}$$

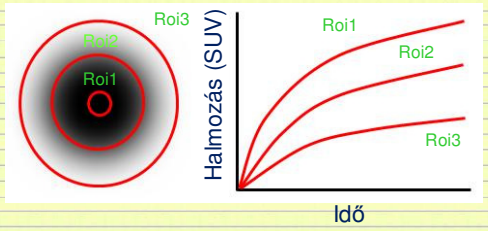
$$SUV\,(t_1,t_2) = \frac{pixel\ \ aktivitás\ \ koncentrác\ ió(t_1,t_2)}{beadott\ \ aktivitás\ /\ testsúly\ \ kg}$$

Megmutatja, hogy egy kiválasztott régióban mérhető aktivitás hányszorosa annak, amit a radiofarmakon feltételezett egyenletes szöveti eloszlása esetén mérhetnénk

A SUV számolás előnyei, tulajdonságai

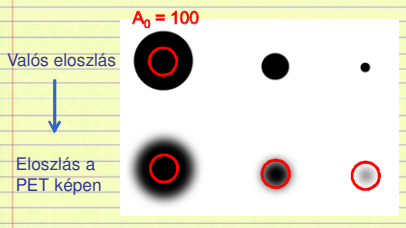
- Egyszerű
- Összehasonlíthatóvá teszi a vizsgálatokat (terápia ellenőrzés)
- Feltételezi, hogy a páciensben a radiofarmakon globális metabolizmusa nem változik a két vizsgálat között (gyakran kérdéses hogy a kiválasztás valóban egyforma-e, vagy pl változó gyulladásos folyamat nem történik-e, …)
- A pontosság további feltételei: a PET kamerát időközönként kalibrálni kell; a leképzés időzítése szigorúan protokoll szerint kell hogy történjen

Region of interest (ROI) és a target terület méretének hatása a SUV-ra



$$SUV(t_1,t_2) = \frac{ROI\ \ aktivitás\ \ koncentráció(t_1,t_2)}{beadott\ \ aktivitás\ /\ testsúly\ \ kg}$$

ROI és target(szerv) méret viszonyának hatása

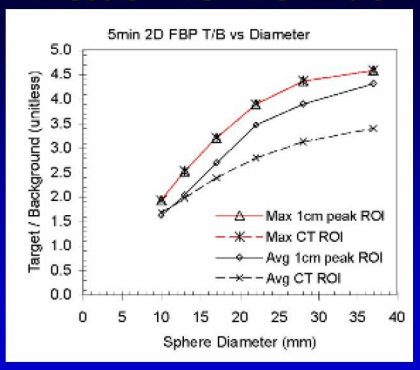


Ha a target „nagy" és a ROI ennél kisebb, akkor a halmozás becslése kis hibával lesz terhelve

Ha a target „kicsi", akkor a ROI-val történő halmozás- mérés mindig alul becsüljük (az alulbecslés mértéke függ a target és ROI méretétől)

$$SUV(t_1,t_2) = \frac{ROI\ \ aktivitás\ \ koncentráció(t_1,t_2)}{beadott\ \ aktivitás\ /\ testsúly\ \ kg}$$

Effect of ROI Definition



Paul Kinahan, SNM 2008

CYRIC Tohoku Univ.

Primary Factors on Quantitative Accuracy in PET Imaging

- Detector Efficiency Non-uniformity
- Attenuation of Annihilation γ-ray
- Resolution (Partial Volume Effect : PVE)
- Random Coincidence
- Scattered Coincidence
- Statistical Error
- Counting Loss

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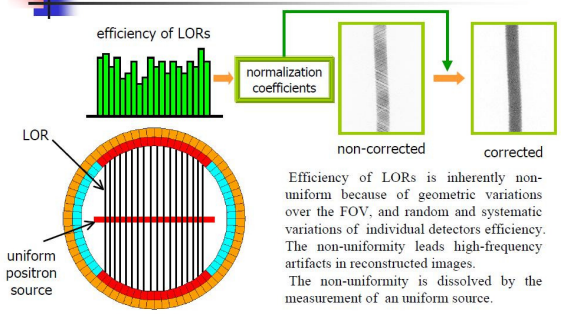
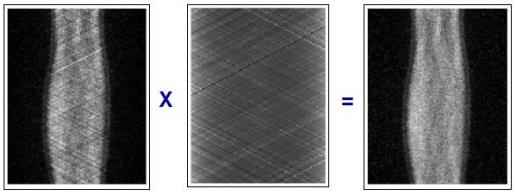
Detector Efficiency Non-uniformity



Efficiency of LORs is inherently non-uniform because of geometric variations over the FOV, and random and systematic variations of individual detectors efficiency. The non-uniformity leads high-frequency artifacts in reconstructed images.
The non-uniformity is dissolved by the measurement of an uniform source.

Normalization



Acquired sinogram | Normalization matrix | Normalized sinogram

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Resolution of PET image

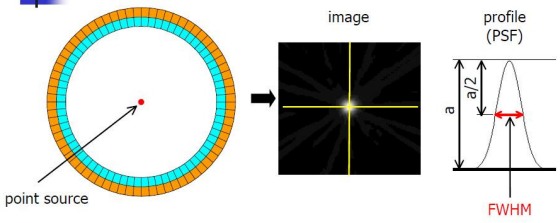

Image resolution is determined by the full width at half maximum (FWHM) of a point spread function (PSF).

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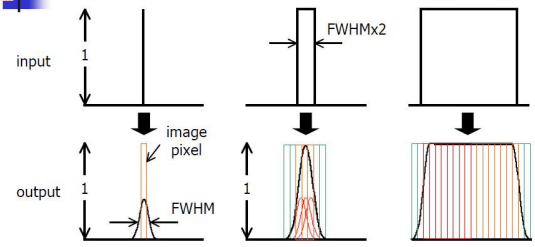
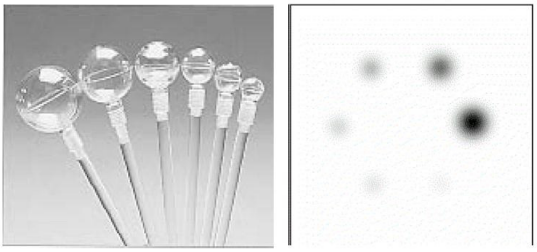
Partial Volume Effect (PVE)



Partial volume effect (PVE) affects the boundary of structures and the quantification of small structures that are smaller than two times of FWHM of PET system .

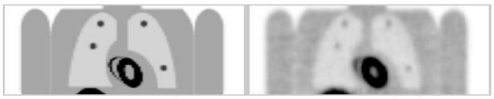
Partial Volume Effect

- Apparent SUV drops with volume
- Also effected by image smoothing



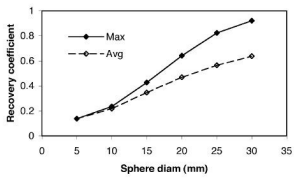
Fillable spheres | Final Image

PET Resolution Losses



true tracer uptake | reconstructed values (scanner resolution + smoothing of noisy data)

- Simulation study with typical imaging protocols
- Limits quantitation in oncology imaging, important for following therapy if size changes



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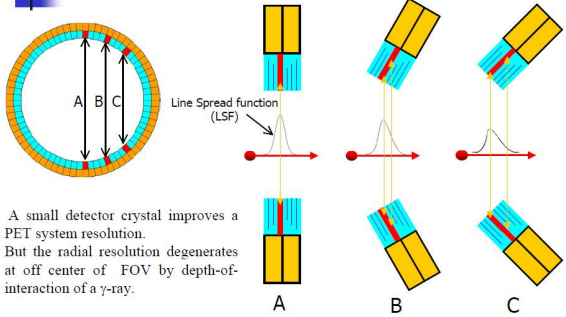
C-3c. Detector Penetration



A small detector crystal improves a PET system resolution.
But the radial resolution degenerates at off center of FOV by depth-of-interaction of a γ-ray.

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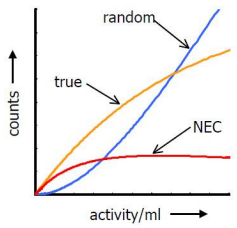
Noise Equivalent Counts (NEC)

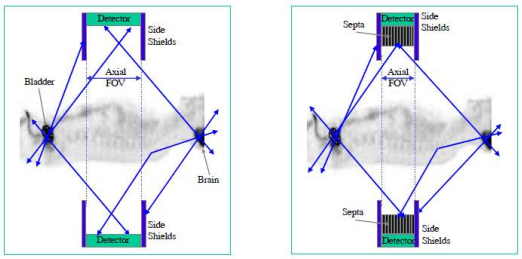


$$NEC = T / (1 + S/T + 2R/T)$$

NEC : noise equivalent count rate
T : true count rate
S : scatter count rate
R : random count rate (delayed coincidence)

True count rate dose not directly indicate the signal-to-noise ratio in a PET image. The NEC defines an effective true count rate by accounting for the additional noise from scatter and random events.

Effect of Activity Beyond Axial FoV



3D 2D

↑Singles, Scatter & Randoms
↓NEC

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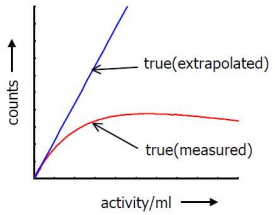
Counting Loss



$$\%DT = (1 - T / T_{extrap}) \times 100$$

$\%DT$: percent dead time
T : measured true events
T_{extrap} : extrapolated true events from low count rate data

Dead time is a period which detector circuits processes input signals. The counting loss due to the dead time and random events becomes important in the case of high activity. The PET images are corrected by using %DT for the loss of events.

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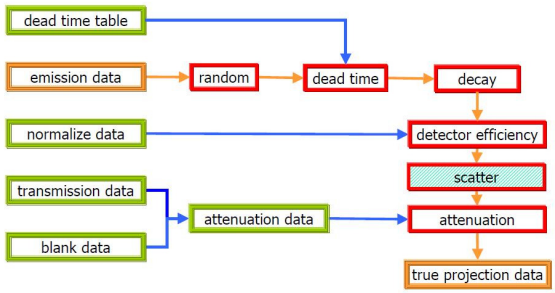
What are needed to obtain true projection data



Performance Measurement Standards

- **NEMA Standards Publication NU 2-1994**: Performance Measurement of Positron Emission Tomographs. National Electrical Manufacturers Association; Washington DC, 1994
- **NEMA Standards Publication NU 2-2001**: Performance Measurement of Positron Emission Tomographs. National Electrical Manufacturers Association; Washington DC, 2001.
- **IEC 61675-1:1998; AS/NZS 4545.1:1999**. Radionuclide imaging devices – Characteristics and test conditions. Part 1: Positron emission tomographs

Tests Performed – NEMA & IEC

Performance Parameter	NEMA	IEC
Spatial Resolution	▯	▯
Sensitivity	▯	▯
Scatter Fraction	▯	▯
Randoms Fraction	▯	ſ§
Count Rate Losses	▯	▯
NEC	▯	ſ§
Correction Accuracy		
Count Losses	▯	▯
Randoms	▯	ſ§
Attenuation	▯	▯
Scatter	▯	ſ§
Image Quality	▯	ſ§

Tests for same performance parameter can vary considerably between NEMA & IEC

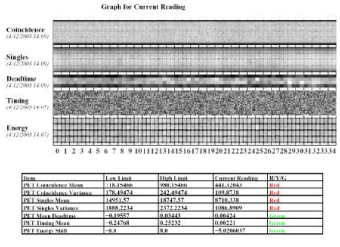
Quality Control

- Depends on Scanner, but some common requirements
- *Detector drift check*
  - Daily, either based on change in sinogram (visual or numeric comparison) or drifts of baseline, peaks
- *Blank Scan for transmission*
  - Daily to weekly for ^{68}Ge, every several months for ^{137}Cs, daily for CT.
- *Absolute activity measurement calibration (SUV)*
  - Every several months or as required
- *Normalisation, calibration (peaks etc)*
  - 1 to several months or as required

Additional QC for PET/CT

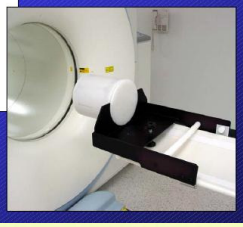
- CT QC
  - Several quick scans to check and calibrate mA, kVp etc
- Spatial co registration between CT and PET
- Check communication between CT and PET

Examples: QA Procedures



Item	Low Limit	High Limit	Current Reading	R/V/G
PET Coincidence Mean	-16.67486	298.17486	440.32943	Red
PET Coincidence Variance	178.47474	242.47474	195.87378	Red
PET Singles Mean	14951.47	18747.57	8716.338	Red
PET Singles Variance	1888.2234	5172.2234	1086.8969	Red
PET Mean Deadtime	-0.19527	0.03443	0.00424	Green
PET Timing Mean	-0.24768	0.25232	0.00221	Green
PET Energy Shift	-8.8	8.8	-0.9266457	Green

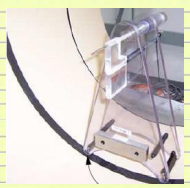
CPS (Siemens-CTI): Obtained with volume phantom (1.5 mCi 68Ge); summary report presented and logged; sinogram viewer for details.



GE: Obtained with rotating line source in gantry. Report generated with fan-sum views and comparisons to previous trends.

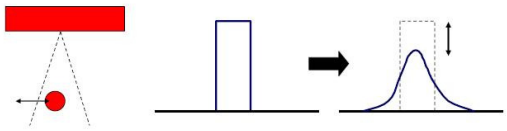
J. A. Anderson 2/18/04

QC at Philips PET



Partial Volume Effect

When an object partially occupies the sensitive volume of an imaging instrument (in space or time) the measured signal will be reduced in amplitude (diluted).

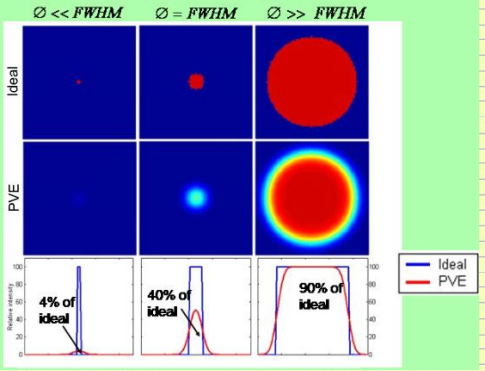


Partial Volume Effect

Causes quantitative errors which depend on:

- Object size
- target : background ratio
- System spatial resolution
- Filtering applied

PVE for different object sizes



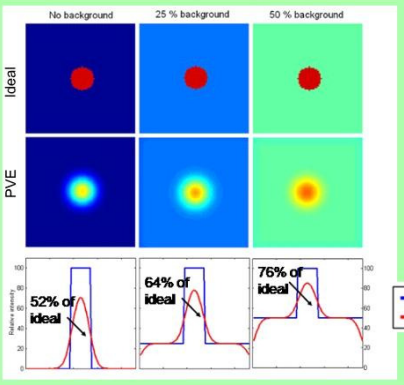
What is PVE?

- PVE is an effect of the limited spatial resolution in the imaging system
- Consequences of PVE:
  - *Qualitative* degradation of the image (blur)
  - Wrong *quantitative* values in objects with sizes comparable to the PSF

Degrading factors in PET

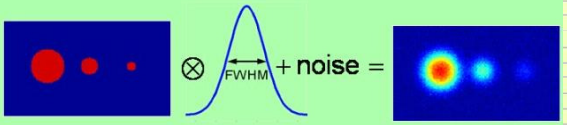
- Physics
  - Positron range
  - Non co-linearity of annihilation photons
  - Photon depth of interaction
  - Random coincidences and photon scattering
- Geometry
  - Finite size of detector elements
  - Reconstruction filters
  - Image sampling

PVE for different background levels



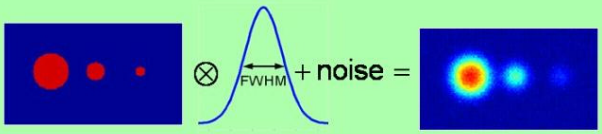
Methods

Image degradation model in 2D



Methods

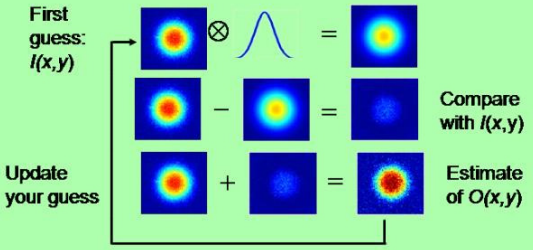
Image degradation model in 2D



$$O(x,y) \otimes PSF(x,y) + \eta(x,y) = I(x,y)$$

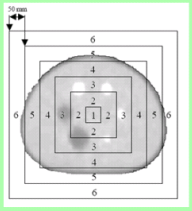
Van Cittert deconvolution algorithm

Estimate $O(x,y)$ from $I(x,y)$ and $PSF(x,y)$



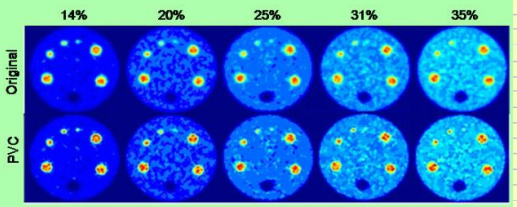
PSF is position variant

- Line source phantom
- Measure the PSF in the central transversal slice at different distances from the centre
- Deconvolve small regions of the image with different PSF:s

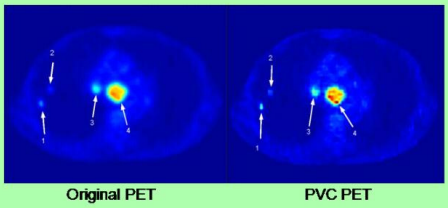


Results - quantitative

Background level



Results – patient image



Profile through tumors